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Radiation Reaction of Charged Particles Orbiting a Magnetized Schwarzschild Black Hole

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Abstract

 In many astrophysically relevant situations, radiation-reaction forces acting upon a charge cannot be ignored, and the question of the location and stability of circular orbits in such a regime arises. The motion of a point charge with radiation reaction in flat spacetime is described by the Lorenz-Dirac (LD) equation, while in curved spacetime it is described by the DeWitt-Brehme (DWB) equation containing the Ricci term and a tail term. We show that for the motion of elementary particles in vacuum metrics, the DWB equation can be reduced to the covariant form of the LD equation, which we use here. Generically, the LD equation is plagued by runaway solutions, so we discuss computational ways of avoiding this problem when constructing numerical solutions. We also use the first iteration of the covariant LD equation, which is the covariant Landau-Lifshitz equation, comparing the results of these two approaches and showing the smallness of the third-order Schott term in the ultrarelativistic case. We calculate the corresponding energy and angular momentum loss of a particle and study the damping of charged particle oscillations around an equilibrium radius. We find that, depending on the orientation of the Lorentz force, the oscillating charged particle either spirals down to the black hole or stabilizes the circular orbit by decaying its oscillations. The latter case leads to the interesting new result of the particle orbit shifting outwards from the black hole. We also discuss the astrophysical relevance of the presented approach and provide estimates of the main parameters of the model.

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Keywords

accretion, accretion disks, black hole physics, magnetic fields, radiation mechanisms: non-thermal, relativistic processes

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